Monoclinic Double Selenates of the Manganese Group.

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Only three salts are included in this group of the series $R_2M(SeO_4)_2.6H_2O$ in which M is manganese, namely, those in which R is rubidium, cæsium, and ammonium, the potassium salt having resisted all attempts at preparation. It will be remembered that the corresponding hexahydrated potassium manganese sulphate has also never been obtained, and appears to be incapable of existence, for even at 0° C. the tetrahydrated salt forms instead. Hence, it is still more improbable that the hexahydrated potassium manganous selenate can exist. In all the author's attempts to prepare it, crystals resembling a dihydrated double selenate of potassium and manganese described by Topsøe were obtained instead.

The rubidium and cæsium salts of the group are now described for the first time. Crystals of the ammonium salt were obtained by von Hauer and measured by Topsøe,* who also determined their density. But no optical investigation of ammonium manganous selenate has hitherto been undertaken, this salt not being included by Topsøe and Christiansen in their well-known research.

The solution of manganous selenate used in preparing the double salts was obtained by digesting for several days, at the ordinary temperature in a covered vessel, excess of specially pure manganous carbonate with a measured quantity of the pure selenic acid prepared for this research by Messrs. Hopkin and Williams. The emulsion was finally filtered and the clear filtrate, consisting of a solution of manganous selenate, was divided into three portions, and each mixed with a solution of the calculated equi-molecular quantity of the alkali selenate, in one case rubidium selenate, in another case cæsium selenate, and in the third case ammonium selenate. These three latter alkali selenates were prepared as described in previous communications.

Excellent crystals, clear and transparent with a faint pink colour, were obtained by slow spontaneous evaporation at ordinary temperature and pressure, and numerous crops were obtained on successive days, from which the most perfect individual crystals were selected for the purpose of this research.

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* Haldor Topsøe, 'Krystallogr.-kem. Unders. o. de Selensure Salte,' Copenhagen, 1870.

Rubidium Manganese Selenate, $Rb_2Mn(SeO_4)_2 \cdot 6H_2O$.

Crystal System.—Monoclinic. Class No. 5, holohedral-prismatic.

Axial Angle.—$\beta = 105° 9'$.

Ratio of Axes.—$a : b : c = 0·7422 : 1 : 0·5008$.

Forms observed.—$a\{100\}$, $b\{010\}$, $c\{001\}$, $p\{110\}$, $p'\{120\}$, $p''\{210\}$, $p'''\{130\}$, $q\{011\}$, $r'\{\bar{2}01\}$, $o'\{\bar{1}11\}$.

Habit.—Typically that of a rubidium salt of the series, characterised by moderate and often nearly equal-sized faces of $q\{011\}$ with respect to those of $c\{001\}$. Two typical crystals are shown in figs. 1 and 2. The crystals of most of the crops were more or less tabular parallel to $c\{001\}$, as shown in fig. 2, but a few crops showed a more nearly prismatic habit, as indicated in the simple crystal represented in fig. 1.

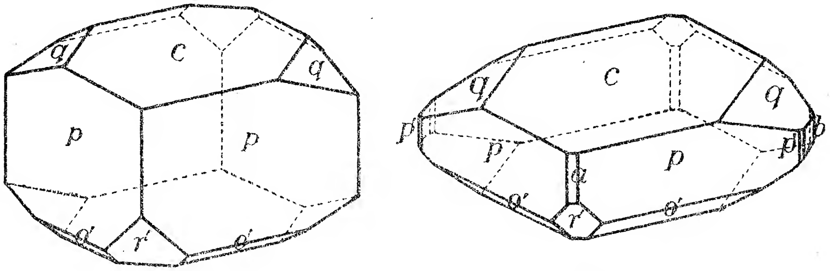


Fig. 1. Fig. 2.

Typical crystals of rubidium manganese selenate.

The faces of $c\{001\}$, $q\{011\}$, and $p\{110\}$ were usually the only ones well developed. Occasionally those of $r'\{\bar{2}01\}$ were fairly prominent, and those of $o'\{\bar{1}11\}$ clearly visible, as in fig. 1. But the faces of $a\{100\}$, $b\{010\}$, $p'\{120\}$, $p'''\{130\}$, and $p''\{210\}$ were always very narrow, usually mere lines, especially the two last mentioned forms. Fig. 2 shows a crystal exhibiting clearly all but these last two forms.

The crystals possessed a faint pink colour, and were beautifully transparent.

The table of angular measurements is given on the next page.

Cleavage.—There is a good cleavage parallel to $r'\{\bar{2}01\}$.

Relative Density.—Six determinations were made by the immersion method using methylene iodide and benzene mixture.

I.	Density for	16°·1/4°	2·7615	For 20°/4°	2·7604
II.	,,	16°·4/4°	2·7618	,, ...	2·7608
III.	,,	16°·8/4°	2·7642	,, ...	2·7633
IV.	,,	16°·6/4°	2·7638	,, ...	2·7629
V.	,,	16°·2/4°	2·7659	,, ...	2·7649
VI.	,,	18°·3/4°	2·7657	,, ...	2·7652
				Mean	2·7629

Accepted value for 20°/4°.........**2·763.**

Interfacial Angles of Rubidium Manganese Selenate.

Angle.	No. of measurements.	Limits.	Mean observed.	Calculated.	Diff.
$ac = (100) : (001)$......	4	74° 39′– 74° 52′	74° 43′	74° 51′	8′
$as = (100) : (101)$......	—	—	—	45 52	
$sc = (101) : (001)$......	—	—	—	28 59	
$cr' = (001) : (\bar{2}01)$......	18	63 22– 63 48	63 33	63 35	2
$cs' = (001) : (\bar{1}01)$......	—	—	—	38 20	
$s'r' = (\bar{1}01) : (\bar{2}01)$......	—	—	—	25 15	
$r'a = (\bar{2}01) : (\bar{1}00)$......	4	41 30– 41 56	41 42	41 34	8
$r'c = (\bar{2}01) : (00\bar{1})$......	19	116 12–116 43	116 27	116 25	2
$ap = (100) : (110)$......	2	35 29– 35 43	35 36	35 38	2
$ap'' = (100) : (210)$......	—	—	—	19 43	
$p''p = (210) : (110)$......	1	—	15 51	15 55	4
$pp' = (110) : (120)$......	2	19 27– 19 37	19 32	19 28	4
$p'p''' = (120) : (130)$......	2	9 53– 10 2	9 58	9 57	1
$p'b = (120) : (010)$......	—	—	—	34 54	
$pp''' = (110) : (130)$......	1	—	29 30	29 25	5
$p'''b = (130) : (010)$......	—	—	—	24 57	
$pb = (110) : (010)$......	2	54 24– 54 29	54 26	54 22	4
$pp = (110) : (1\bar{1}0)$......	23	71 4– 71 27	71 15	*	
$pp = (110) : (\bar{1}10)$......	23	108 32–108 57	108 45	108 45	0
$cq = (001) : (011)$......	41	25 39– 25 57	25 48	*	
$qb = (011) : (010)$......	—	—	—	64 12	
$qq = (011) : (01\bar{1})$......	21	128 14–128 39	128 24	128 24	0
$ao = (100) : (111)$......	—	—	—	49 4	
$oq = (111) : (011)$......	—	—	—	27 19	
$aq = (100) : (011)$......	—	—	—	76 23	
$qo' = (011) : (\bar{1}11)$......	—	—	—	34 33	
$o'a = (\bar{1}11) : (\bar{1}00)$......	—	—	—	69 4	
$co = (001) : (111)$......	—	—	—	34 35	
$op = (111) : (110)$......	—	—	—	43 9	
$cp = (001) : (110)$......	40	77 35– 77 55	77 44	*	
$po' = (110) : (11\bar{1})$......	5	57 31– 57 47	57 40	57 44	4
$o'c = (11\bar{1}) : (00\bar{1})$......	5	44 28– 44 48	44 36	44 32	4
$pc = (110) : (00\bar{1})$......	40	102 3–102 29	102 16	102 16	0
$bn = (010) : (121)$......	—	—	—	54 18	
$no = (121) : (111)$......	—	—	—	15 56	
$bo = (010) : (111)$......	—	—	—	70 14	
$os = (111) : (101)$......	—	—	—	19 46	
$bo' = (010) : (\bar{1}11)$......	—	—	—	65 17	
$o's' = (\bar{1}11) : (\bar{1}01)$......	—	—	—	24 43	
$o'o' = (\bar{1}11) : (\bar{1}\bar{1}1)$......	—	—	—	49 26	
$sq = (101) : (011)$......	—	—	—	38 2	
$qp = (011) : (\bar{1}10)$......	40	86 14– 86 42	86 28	86 26	2
$ps = (\bar{1}10) : (\bar{1}0\bar{1})$......	—	—	—	55 32	
$pq = (\bar{1}10) : (0\bar{1}\bar{1})$......	40	93 21– 93 43	93 31	93 34	3
$s'q = (\bar{1}01) : (011)$......	—	—	—	45 4	
$qn = (011) : (121)$......	—	—	—	26 41	
$np = (121) : (110)$......	—	—	—	36 55	
$qp = (011) : (110)$......	40	63 16– 63 47	63 34	63 36	2
$ps' = (110) : (10\bar{1})$......	—	—	—	71 20	
$pq = (110) : (0\bar{1}\bar{1})$......	40	116 10–116 42	116 26	116 24	2
$r'o' = (\bar{2}01) : (\bar{1}11)$......	7	34 37– 34 46	34 40	34 45	5
$o'p = (\bar{1}11) : (110)$......	6	92 35– 92 53	92 43	92 42	1
$pr' = (110) : (20\bar{1})$......	30	52 24– 52 49	52 37	52 33	4
$r'p = (\bar{2}01) : (110)$......	34	127 10–127 34	127 23	127 27	4
Total (11 crystals) ...	490				

Molecular Volume.—$\frac{M}{d} = \frac{615 \cdot 92}{2 \cdot 763} = 222 \cdot 92$.

Molecular Distance Ratios (topic axial ratios).—

$$\chi : \psi : \omega = 6 \cdot 3333 : 8 \cdot 5332 : 4 \cdot 2734.$$

Orientation of Optical Ellipsoid.—Plane of optic axes $b\{010\}$. Sign of double refraction, positive. The first median line is the γ axis of the indicatrix, and the second median line is α.

Extinction Direction (Axis α) in Symmetry Plane.

Plate I......1° 51′, Plate II......2° 12′, Mean......2° 2′,

behind the normal to c(001), towards the vertical axis c.

As that normal is 15° 9′ in front of the vertical axis, the second median line, the extinction direction in question, is 13° 7′ in front of the vertical axis c. The first median line lies 2° 2′ above the axis a. Both median lines thus lie in the obtuse axial angle ac. Fig. 3 will render the conditions clear.

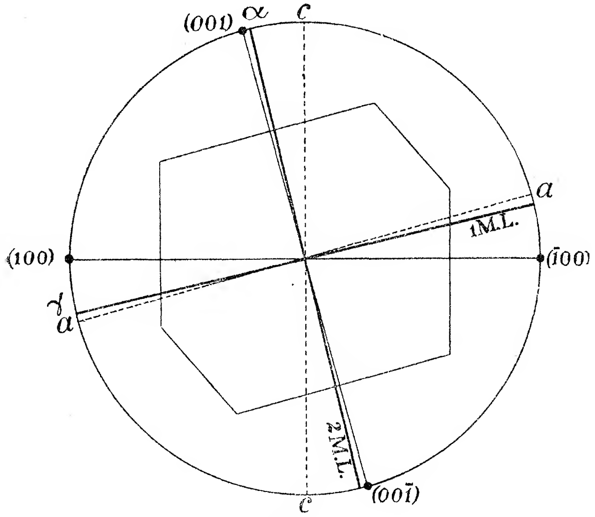


Fig. 3.

Optic Axial Angle.—Results with three pairs of section-plates perpendicular to the two median lines.

Apparent Optic Axial Angle in Air, 2E, of RbMn Selenate.

Light.	Plate I.	Plate II.	Plate III.	Mean 2E.
	° ′	° ′	° ′	° ′
Li....................	112 1	112 12	112 20	112 11
C	112 2	112 13	112 22	112 12
Na	112 14	112 24	112 35	112 24
Tl	112 23	112 36	112 47	112 35
Cd	112 32	112 44	112 54	112 43

Determination of True Optic Axial Angle in Bromonaphthalene.

Light.	No. of plate perp. 1 M.L.	Observed $2H_a$.	No. of plate perp. 2 M.L.	Observed $2H_o$.	Calculated $2V_a$.	Mean $2V_a$.
		° ′		° ′	° ′	° ′
Li	1	59 46	1*a*	99 36	66 14	66 5
	2	59 18	2*a*	99 46	65 48	
	3	59 44	3*a*	99 38	66 12	
C	1	59 44	1*a*	99 32	66 14	66 5
	2	59 16	2*a*	99 43	65 48	
	3	59 42	3*a*	99 34	66 12	
Na	1	59 33	1*a*	99 12	66 13	66 2
	2	59 4	2*a*	99 25	65 45	
	3	59 26	3*a*	99 11	66 8	
Tl	1	59 16	1*a*	98 40	66 12	66 0
	2	58 46	2*a*	98 51	65 43	
	3	59 10	3*a*	98 50	66 4	
Cd	1	59 4	1*a*	98 23	66 9	65 57
	2	58 36	2*a*	98 32	65 42	
	3	58 56	3*a*	98 28	66 0	
F	1	58 46	1*a*	98 3	66 2	65 52
	2	58 25	2*a*	98 14	65 41	
	3	58 38	3*a*	98 11	65 52	

Dispersion of the Median Lines.—This is very small, measurements in monochlorobenzene (of similar refractive index) having indicated that the first median line lies nearer to the inclined axis *a* by 8 minutes for red C hydrogen light than for green cadmium light.

Effect of Temperature on Optic Axial Angle.—Determinations at a series of temperatures up to 75° C. indicated that the optic axial angle in air, 2E, diminishes by 3½° for the 60° of rise of temperature, from 15° to 75° C.

Refractive Indices.—Determinations obtained with six 60°-prisms, each ground to afford two indices directly, afforded the following mean values.

Refractive Indices of Rubidium Manganese Selenate.

Light.	α.	β.	γ.
Li	1·5059	1·5105	1·5220
C	1·5064	1·5110	1·5226
Na	1·5094	1·5140	1·5258
Tl	1·5125	1·5172	1·5292
Cd	1·5143	1·5190	1·5312
F	1·5163	1·5210	1·5332
G	1·5225	1·5270	1·5396

Mean of α, β, and γ for Na light = 1·5164.

α = Vibration direction parallel to second median line, 13° 7′ in front of axis *c*.
β = " " " symmetry axis *b*.
γ = " " " first median line, 2° 2′ above axis *a*.

Double refraction, $\mathrm{Na}_{\gamma-\alpha}$ = 0·0164.

General formula for β, corrected to a vacuum :—

$$\beta = 1{\cdot}4978 + \frac{623\ 971}{\lambda^2} - \frac{1\ 653\ 300\ 000\ 000}{\lambda^4} + \ldots .$$

The α indices are also reproduced by the formula if the constant 1·4978 be diminished by 0·0046, and the γ indices if it be increased by 0·0118.

Observations at 65° indicated that the refractive indices diminish with rise of temperature, to the extent of 0·0013 for 50° rise of temperature.

Axial Ratios of the Optical Ellipsoid—

$\alpha : \beta : \gamma = 0{\cdot}9969 : 1 : 1{\cdot}0078$, $\mathfrak{a} : \mathfrak{b} : \mathfrak{c} = 1{\cdot}0031 : 1 : 0{\cdot}9923$.

Molecular Optical Constants.

	Axis of optical indicatrix.		α.	β.	γ.
Lorenz	Specific refraction, $\frac{n^2-1}{(n^2+2)d} = \mathfrak{n}$.........	C	0·1076	0·1084	0·1105
		G	0·1105	0·1113	0·1135
	Molecular refraction, $\frac{n^2-1}{n^2+2} \cdot \frac{M}{d} = \mathfrak{m}$...	C	66·27	66·78	68·06
		G	68·04	68·53	69·90
	Specific dispersion, $\mathfrak{n}_G - \mathfrak{n}_C$		0·0029	0·0029	0·0030
	Molecular dispersion, $\mathfrak{m}_G - \mathfrak{m}_C$		1·77	1·75	1·84
Gladstone...	Molecular refraction, $\frac{n-1}{d}M$	C	112·88	113·91	116·50

Mean molecular refraction (Gladstone), $\frac{1}{3}(\alpha + \beta + \gamma) = 114{\cdot}43$.

Cæsium Manganese Selenate, $Cs_2Mn(SeO_4)_2 . 6H_2O$.

Crystal System.—Monoclinic. Class No. 5, holohedral-prismatic.

Axial Angle.—$\beta = 106° \ 22'$.

Ratio of Axes.—$a : b : c = 0{\cdot}7319 : 1 : 0{\cdot}4957$.

Forms observed.—$a\{100\}$, $b\{010\}$, $c\{001\}$, $p\{110\}$, $p'\{120\}$, $p'''\{130\}$, $q\{011\}$, $r'\{\bar{2}01\}$, $o'\{\bar{1}11\}$.

Habit.—That characteristic of the cæsium salts of the series, namely, more or less narrow $c\{001\}$ faces, broader $q\{011\}$ faces, and only moderately prominent $p\{110\}$ faces, scarcely ever tall enough to impart prismatic habit parallel to the vertical axis, although the crystals are often prismatic parallel to the inclined axis a. Fig. 4 represents a typical crystal.

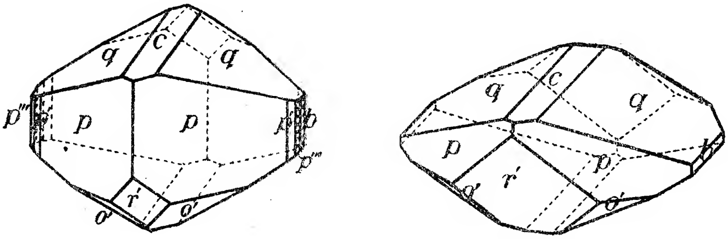


Fig. 4. Fig. 5.

Typical crystals of cæsium manganese selenate.

The $r'\{\bar{2}01\}$ faces were almost always better developed than usual, and sometimes were as relatively large as shown in fig. 5. Faces of the subsidiary prisms $p'\{120\}$, and $p'''\{130\}$, were nearly always present, and the hemi-pyramid $o'\{\bar{1}11\}$ faces were also ubiquitous and often quite well developed. The clinopinakoid $b\{010\}$ was sometimes present as a fairly broad strip, but usually was very narrow or absent. The orthopinakoid $a\{100\}$ was only found as a very narrow strip, practically a line. A table of angles is given on the next page.

The crystals of this salt are particularly brilliant and transparent, and exhibit a faint pink colour.

Cleavage.—That common to the series, parallel $r'\{\bar{2}01\}$, perfect.

Relative Density.—Six determinations were carried out by the immersion method on crystals small and perfectly clear.

I.	Density for	18°·2/4°	3·0086	For 20°/4°	3·0081
II.	„	17°·6/4°	3·0037	„	3·0030
III.	„	15°·5/4°	3·0129	„	3·0115
IV.	„	17°·6/4°	3·0105	„	3·0098
V.	„	17°·4/4°	3·0094	„	3·0086
VI.	„	17°·6/4°	3·0094	„	3·0087
				Mean	3·0083

Accepted value for 20°/4°......**3·008**.

Molecular Volume.—$\frac{M}{d} = \frac{709{\cdot}92}{3{\cdot}008} = 236{\cdot}01.$

Molecular Distance (topic axial) ratios.—

$$\chi : \psi : \omega = 6{\cdot}4297 : 8{\cdot}7850 : 4{\cdot}3547.$$

Orientation of Optical Ellipsoid.—Plane of optic axes $b\{010\}$. Sign of double refraction positive. The first median line is the γ axis of the indicatrix, and the second line median is α.

Extinction Direction (2 M.L.) in Symmetry Plane.

Plate I......5° 52′, Plate II......5° 45′,
Mean extinction angle......... 5° 49′,

in front of the normal to $c\{001\}$ and away from the vertical axis c. As that normal is 16° 22′ in front of the vertical axis, this extinction direction, which is that of the second median line, is situated 22° 11′ in front of the vertical axis c. The first median line is 5° 49′ below the axis a. These dispositions will be clear from fig. 6.

Interfacial Angles of Cæsium Manganese Selenate.

Angle.	No. of measurements.	Limits.	Mean observed.	Calculated.	Diff.
$ac = (100) : (001)$......	4	73° 29′– 73° 42′	73° 35′	73° 38′	3′
$as = (100) : (101)$......	—	—	—	44 59	
$sc = (101) : (001)$......	—	—	—	28 39	
$cr' = (001) : (\bar{2}01)$......	17	64 26– 64 48	64 35	64 35	0
$cs' = (001) : (\bar{1}01)$......	—	—	—	38 48	
$s'r' = (\bar{1}01) : (\bar{2}01)$......	—	—	—	25 47	
$r'a = (\bar{2}01) : (\bar{1}00)$......	8	41 25– 42 5	41 50	41 47	3
$r'c = (\bar{2}01) : (00\bar{1})$......	17	115 16–115 34	115 25	115 25	0
$ap = (100) : (110)$......	2	34 56– 35 4	35 0	35 4	4
$ap'' = (100) : (210)$......	—	—	—	19 20	
$p''p = (210) : (110)$......	—	—	—	15 44	
$pp' = (110) : (120)$......	14	19 10– 19 48	19 27	19 28	1
$p'p''' = (120) : (130)$......	2	9 45– 10 14	10 0	10 3	3
$p'b = (120) : (010)$......	7	35 20– 35 45	35 35	35 28	7
$pp''' = (110) : (130)$......	4	29 16– 30 2	29 31	29 31	0
$p'''b = (130) : (010)$......	4	25 28– 25 35	25 30	25 25	5
$pb = (110) : (010)$......	17	54 42– 55 17	54 57	54 56	1
$pp = (110) : (1\bar{1}0)$......	21	70 0– 70 19	70 7	*	
$pp = (110) : (\bar{1}10)$......	22	109 32–109 59	109 51	109 53	2
$cq = (001) : (011)$......	39	25 18– 25 37	25 26	*	
$qb = (011) : (010)$......	16	64 27– 64 39	64 34	64 34	0
$qq = (011) : (01\bar{1})$......	18	128 55–129 14	129 7	129 8	1
$ao = (100) : (111)$......	—	—	—	48 7	
$oq = (111) : (011)$......	—	—	—	27 8	
$aq = (100) : (011)$......	—	—	—	75 15	
$qo' = (011) : (\bar{1}11)$......	—	—	—	35 3	
$o'a = (\bar{1}11) : (\bar{1}00)$......	—	—	—	69 42	
$co = (001) : (111)$......	—	—	—	34 5	
$op = (111) : (110)$......	—	—	—	42 35	
$cp = (001) : (110)$......	38	76 22– 76 49	76 40	*	
$po' = (110) : (11\bar{1})$......	31	58 15– 58 48	58 26	58 27	1
$o'c = (11\bar{1}) : (00\bar{1})$......	32	44 32– 45 13	44 53	44 53	0
$pc = (110) : (00\bar{1})$......	38	103 8–103 33	103 20	103 20	0
$bn = (010) : (121)$......	—	—	—	54 58	
$no = (121) : (111)$......	—	—	—	15 43	
$bo = (010) : (111)$......	—	—	—	70 41	
$os = (111) : (101)$......	—	—	—	19 19	
$bo' = (010) : (\bar{1}11)$......	24	65 19– 65 31	65 26	65 23	3
$o's' = (\bar{1}11) : (\bar{1}01)$......	—	—	—	24 37	
$o'o' = (\bar{1}11) : (\bar{1}\bar{1}1)$......	9	49 5– 49 19	49 12	49 14	2
$sq = (101) : (011)$......	—	—	—	37 35	
$qp = (011) : (\bar{1}10)$......	40	87 36– 88 8	87 50	87 48	2
$ps = (\bar{1}10) : (\bar{1}0\bar{1})$......	—	—	—	54 37	
$pq = (\bar{1}10) : (0\bar{1}\bar{1})$......	40	91 57– 92 23	92 11	92 12	1
$s'q = (\bar{1}01) : (011)$......	—	—	—	45 16	
$qn = (011) : (121)$......	—	—	—	26 26	
$np = (121) : (110)$......	—	—	—	36 30	
$qp = (011) : (110)$......	42	62 46– 63 2	62 55	62 56	1
$ps' = (110) : (10\bar{1})$......	—	—	—	71 48	
$pq = (110) : (0\bar{1}\bar{1})$......	41	116 58–117 14	117 5	117 4	1
$r'o' = (\bar{2}01) : (\bar{1}11)$......	30	34 49– 35 15	35 1	35 3	2
$o'p = (\bar{1}11) : (110)$......	30	92 20– 92 48	92 35	92 34	1
$pr' = (110) : (20\bar{1})$......	32	52 17– 52 40	52 24	52 23	1
$r'p = (\bar{2}01) : (110)$......	32	127 15–127 42	127 36	127 37	1
Total (11 crystals) ...	671				

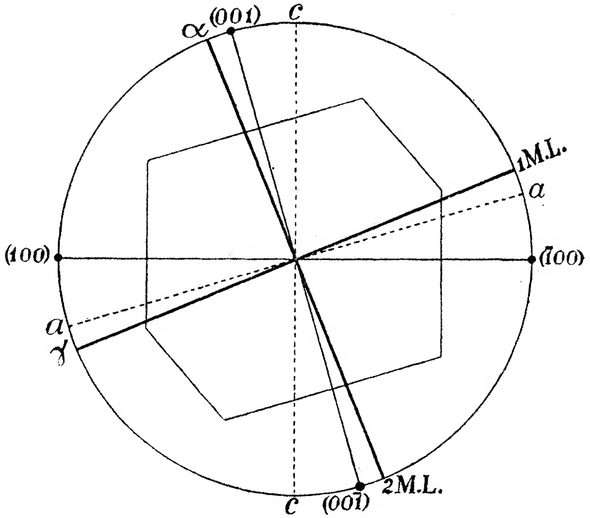


Fig. 6.

Optic Axial Angle.—Results with three pairs of plates ground perpendicular to the first and second median lines.

Apparent Optic Axial Angle in Air, 2E, of CsMn Selenate.

Light.	Plate 1.	Plate 2.	Plate 3.	Mean 2E.
	° ′	° ′	° ′	° ′
Li……………………	121 27	119 46	121 30	120 54
C ……………………	121 23	119 42	121 26	120 50
Na …………………	120 48	119 18	121 0	120 22
Tl……………………	120 29	119 3	120 42	120 5
Cd …………………	120 8	118 50	120 13	119 44

Determination of True Optic Axial Angle in Bromonaphthalene.

Light.	No. of plate perp. 1 M.L.	Observed $2H_a$.	No. of plate perp. 2 M.L.	Observed $2H_o$.	Calculated $2V_a$.	Mean $2V_a$.
		° ′		° ′	° ′	° ′
Li………	1 …………	62 56	1*a*	98 31	69 8	
	2 …………	62 56	2*a*	98 54	68 59	69 3
	3 …………	63 5	3*a*	99 4	69 2	
C ………	1 …………	62 51	1*a*	98 29	69 5	
	2 …………	62 52	2*a*	98 50	68 57	69 1
	3 …………	63 1	3*a*	99 1	69 0	
Na ……	1 …………	62 30	1*a*	98 16	68 54	
	2 …………	62 28	2*a*	98 21	68 50	68 49
	3 …………	62 32	3*a*	98 45	68 44	
Tl………	1 …………	61 56	1*a*	98 4	68 32	
	2 …………	61 59	2*a*	97 56	68 38	68 33
	3 …………	62 3	3*a*	98 30	68 28	
Cd ……	1 …………	61 28	1*a*	97 56	68 14	
	2 …………	61 31	2*a*	97 48	68 20	68 17
	3 …………	61 46	3*a*	98 24	68 17	
F ………	1 …………	61 7	1*a*	97 45	68 2	
	2 …………	61 11	2*a*	97 30	68 11	68 5
	3 …………	61 22	3*a*	98 14	68 2	

Dispersion of the Median Lines.—The first median line is dispersed so that for cadmium green light it is 10 minutes nearer to the axis *a* than for red C-light. The determination was made during immersion of the section plate 1, 2, or 3 in methyl salicylate, the refraction of which is almost exactly the same as the mean refraction of the crystal.

Effect of Temperature on Optic Axial Angle.—On heating one of the section-plates gradually to 70° C., the optic axial angle in air 2E diminished to 115° 5′ for sodium light, a diminution of 5° for 55° of rise of temperature.

Refractive Indices.—Results with six 60°-prisms, each ground to afford two indices directly—

Refractive Indices of Cæsium Manganese Selenate.

Light.	α.	β.	γ.
Li................	1·5215	1·5243	1·5301
C................	1·5220	1·5248	1·5306
Na	1·5250	1·5279	1·5338
Tl	1·5283	1·5312	1·5373
Cd	1·5302	1·5331	1·5394
F................	1·5323	1·5350	1·5415
G................	1·5379	1·5405	1·5471

Mean of α, β, and γ for Na light = 1·5289.

α = Vibration direction parallel to second median line, 22° 11′ in front of axis *c*.
β = ,, ,, ,, symmetry axis *b*.
γ = ,, ,, ,, first median line, 5° 49′ below axis *a*.

Double refraction, $\mathrm{Na}_{\gamma-\alpha}$ = 0·0088.

General formula for the intermediate refractive index β, corrected to a vacuum (correction + 0·0004):—

$$\beta = 1{\cdot}5112 + \frac{641\ 068}{\lambda^2} - \frac{1\ 646\ 000\ 000\ 000}{\lambda^4} + \dots$$

The α indices are also reproduced very closely by the formula if the constant 1·5112 be diminished by 0·0029 and the γ indices if the constant be increased by 0·0059.

Observations at 65° C. showed that the refractive indices are diminished by about 0·0013 (varying from 0·0011 for α to 0·0016 for γ) for 50° rise of temperature.

Axial Ratios of the Optical Ellipsoid—

$\alpha : \beta : \gamma = 0{\cdot}9981 : 1 : 1{\cdot}0039$, $\mathfrak{a} : \mathfrak{b} : \mathfrak{c} = 1{\cdot}0019 : 1 : 0{\cdot}9961$.

Molecular Optical Constants.

	Axis of optical indicatrix.		α.	β.	γ.
Lorenz	Specific refraction, $\frac{n^2-1}{(n^2+2)d} = \mathfrak{n}$	C	0·1014	0·1018	0·1028
		G	0·1040	0·1044	0·1054
	Molecular refraction, $\frac{n^2-1}{n^2+2} \cdot \frac{M}{d} = \mathfrak{m}$...	C	71·98	72·30	72·97
		G	73·81	74·10	74·86
	Specific dispersion, $\mathfrak{n}_G - \mathfrak{n}_C$		0·0026	0·0026	0·0026
	Molecular dispersion, $\mathfrak{m}_G - \mathfrak{m}_C$		1·83	1·80	1·89
Gladstone...	Molecular refraction, $\frac{n-1}{d}$ M	C	123·20	123·86	125·23

Mean molecular refraction (Gladstone), $\frac{1}{3}(\alpha+\beta+\gamma) = 124\cdot10$.

Ammonium Manganese Selenate $(NH_4)_2Mn(SeO_4)_2 . 6H_2O$.

Crystal System.—Monoclinic. Class No. 5, holohedral-prismatic.

Axial Angle.—β = 106° 16′. The value found by Topsøe was 106° 14′.

Ratio of Axes.—$a : b : c = 0{\cdot}7427 : 1 : 0{\cdot}4994$.

Topsøe's values 0·7416 : 1 : 0·4979.

Forms observed.—$a\{100\}$, $b\{010\}$, $c\{001\}$, $p\{110\}$, $p'\{120\}$, $p''\{210\}$, $p'''\{130\}$, $q\{011\}$, $o'\{\bar{1}11\}$, $r'\{\bar{2}01\}$, $n'\{\bar{1}21\}$.

The forms a and p'' were not observed by Topsøe.

Habit.—A great variety of habit is exhibited by this salt, but figs. 7 and 8 are typical illustrations. A more or less tabular form, parallel to a pair of either $c\{001\}$, $p\{110\}$, or $r'\{\bar{2}01\}$ faces (see fig. 3, p. 250, illustrating ammonium cadmium selenate), is common. Occasionally a prismatic habit parallel to the vertical axis is observed, like fig. 7 but more elongated vertically. The $q\{011\}$ faces show every variety of relative size, from small (characteristic of the potassium salts of the series) to about as large as the c faces (characteristic of the rubidium salts), as shown in figs. 7 and 8. Very often no faces are apparent but those of $c\{001\}$, $q\{011\}$, $p\{110\}$, and $r'\{\bar{2}01\}$. The subordinate

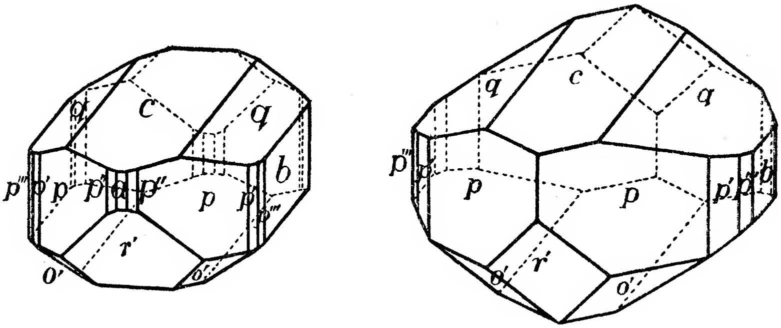


Fig. 7. Fig. 8.

Typical crystals of ammonium manganese selenate.

prism-faces $p'\{120\}$, $p'''\{130\}$, and $p''\{210\}$ were usually mere lines, but in certain crops of larger crystals quite large faces of $p'\{120\}$ and $p'''\{130\}$ were present, as shown in fig. 8. The faces of the hemi-pyramid $o'\{\bar{1}11\}$ were often fairly considerably developed when present at all, but the rarer form $n'\{\bar{1}21\}$ was never developed sufficiently to afford measurements more than merely adequate for identification. The results of the measurements are given on the next page.

The crystals were beautifully clear and transparent and exhibited a faint pink colour.

Cleavage.—The usual cleavage parallel to $r'\{\bar{2}01\}$ common to the series is exhibited, and also an even more perfect one parallel to $b\{010\}$.

Relative Density.—Six determinations were made by the immersion method, with excellent small crystals.

I.	Density for	18°·9/4°	2·1606	For 20°/4°	2·1604
II.	,,	18°·2/4°	2·1551	,, ...	2·1547
III.	,,	19°·1/4°	2·1614	,, ...	2·1612
IV.	,,	19°·1/4°	2·1562	,, ...	2·1560
V.	,,	19°·8/4°	2·1598	,, ...	2·1598
VI.	,,	19°·5/4°	2·1578	,, ...	2·1577
				Mean	2·1583

Accepted value for 20°/4°......**2·158.**

Molecular Volume.—$\frac{M}{d} = \frac{481{\cdot}98}{2{\cdot}158} = 223{\cdot}35.$

Topsøe obtained the lower value 2·093 for the specific gravity, and consequently also a molecular volume too high, namely, 232·2.

Molecular Distance (topic axial) ratios.—

$$\chi : \psi : \omega = 6{\cdot}3577 : 8{\cdot}5603 : 4{\cdot}2750.$$

Orientation of Optical Ellipsoid.—Plane of optic axes $b\{010\}$. Sign of double refraction, positive. The first median line is the γ axis of the indicatrix, and α is the second median line.

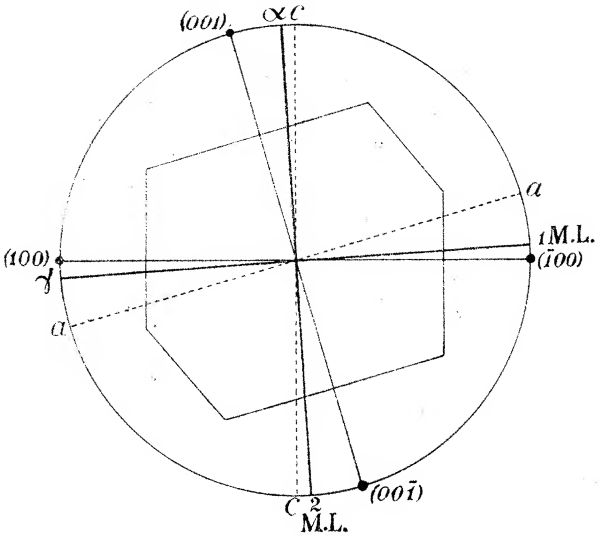
Extinction Direction (2M.L.) in Symmetry Plane.

Plate I...13° 12′, Plate II...13° 20′, Plate III...12° 10′, Mean...12° 54′, behind the normal to $c\{001\}$. As the normal to $c\{001\}$ lies 16° 16′ in front of the vertical axis c, this extinction direction, which is the second median line, lies 3° 22′ in front of the vertical axis. The first median line lies 12° 54′ above the axis a. Both median lines thus lie in the obtuse axial angle ac. Fig. 9 will render the conditions clear.

Interfacial Angles of Ammonium Manganese Selenate.

Angle.	No. of measurements.	Limits.	Mean observed.	Calculated.	Diff.	Topsøe's values.
$ac = (100) : (001)$...	3	73° 30′– 73° 53′	73° 44′	73° 44′	0′	73° 46′
$as = (100) : (101)$...	—	—	—	45 14	—	
$sc = (101) : (001)$...	—	—	—	28 30	—	
$cr' = (001) : (\bar{2}01)$...	20	63 58– 64 25	64 10	64 12	2	64 8
$cs' = (001) : (\bar{1}01)$...	—	—	—	38 28	—	
$s'r' = (\bar{1}01) : (\bar{2}01)$...	—	—	—	25 44	—	
$r'a = (\bar{2}01) : (\bar{1}00)$...	2	41 54– 42 16	42 5	42 4	1	
$r'c = (\bar{2}01) : (00\bar{1})$...	20	115 35–116 3	115 50	115 48	2	115 52
$ap = (100) : (110)$...	6	35 23– 35 34	35 27	35 29	2	
$ap'' = (100) : (210)$...	1	—	19 40	19 37	3	
$p''p = (210) : (110)$...	1	—	15 54	15 52	2	
$pp' = (110) : (120)$...	1	—	19 25	19 28	3	19 28
$p'b = (120) : (010)$...	1	—	35 6	35 3	3	35 5
$pp''' = (110) : (130)$...	3	29 12– 29 32	29 21	29 27	6	29 28
$p'''b = (130) : (010)$...	2	24 59– 25 1	25 0	25 4	4	25 5
$p'p''' = (120) : (130)$...	—	—	—	9 59	—	10 0
$pb = (110) : (010)$...	27	54 8– 54 46	54 31	54 31	0	54 33
$pp = (110) : (1\bar{1}0)$...	22	70 42– 71 15	70 58	*	—	70 54
$pp = (110) : (\bar{1}10)$...	20	108 41–109 28	109 3	109 2	1	109 6
$cq = (001) : (011)$...	42	25 22– 25 50	25 37	*	—	25 33
$qb = (011) : (010)$...	31	64 12– 64 38	64 24	64 23	1	64 27
$qq = (011) : (01\bar{1})$...	20	128 24–129 13	128 47	128 46	1	128 54
$ao = (100) : (111)$...	—	—	—	48 25	—	
$oq = (111) : (011)$...	—	—	—	26 57	—	
$aq = (100) : (011)$...	—	—	—	75 22	—	75 23
$qo' = (011) : (\bar{1}11)$...	—	—	—	34 43	—	34 40
$o'a = (\bar{1}11) : (\bar{1}00)$...	—	—	—	69 55	—	
$co = (001) : (111)$...	—	—	—	34 5	—	
$op = (111) : (110)$...	—	—	—	42 44	—	
$cp = (001) : (110)$...	42	76 38– 77 3	76 49	*	—	76 50
$po' = (110) : (11\bar{1})$...	22	58 12– 58 51	58 33	58 27	6	
$o'c = (11\bar{1}) : (00\bar{1})$...	22	44 21– 45 12	44 38	44 44	6	44 38
$pc = (110) : (00\bar{1})$...	42	103 0–103 25	103 11	103 11	0	103 10
$bn = (010) : (121)$...	—	—	—	54 39	—	
$no = (121) : (111)$...	—	—	—	15 50	—	
$bo = (010) : (111)$...	—	—	—	70 29	—	
$os = (111) : (101)$...	—	—	—	19 31	—	
$bn' = (010) : (\bar{1}21)$...	—	—	—	47 14	—	
$n'o' = (\bar{1}21) : (\bar{1}11)$...	—	—	—	17 57	—	
$bo' = (010) : (\bar{1}11)$...	14	65 0– 65 28	65 12	65 11	1	65 15
$o's' = (\bar{1}11) : (\bar{1}01)$...	—	—	—	24 49	—	24 45
$o'o' = (\bar{1}11) : (\bar{1}\bar{1}1)$...	3	49 35– 49 40	49 38	49 38	0	49 29
$sq = (101) : (011)$...	—	—	—	37 35	—	
$qn' = (011) : (\bar{1}21)$...	—	—	—	35 43	—	
$n'p = (\bar{1}21) : (\bar{1}10)$...	—	—	—	51 41	—	
$qp = (011) : (\bar{1}10)$...	34	87 18– 87 39	87 28	87 24	4	87 26
$ps = (\bar{1}10) : (\bar{1}0\bar{1})$...	—	—	—	55 1	—	
$pq = (\bar{1}10) : (0\bar{1}\bar{1})$...	34	92 22– 92 40	92 34	92 36	2	
$s'q = (\bar{1}01) : (011)$...	—	—	—	45 5	—	
$qn = (011) : (121)$...	—	—	—	26 18	—	
$np = (121) : (110)$...	—	—	—	36 32	—	
$qp = (011) : (110)$...	37	62 41– 63 6	62 55	62 50	5	62 54
$ps' = (110) : (10\bar{1})$...	—	—	—	72 5	—	
$pq = (110) : (0\bar{1}\bar{1})$...	37	116 49–117 19	117 5	117 10	5	
$r'o' = (\bar{2}01) : (\bar{1}11)$...	23	34 56– 35 43	35 11	35 9	2	35 5
$o'p = (\bar{1}11) : (110)$...	20	91 47– 92 16	91 59	92 3	4	
$pr' = (110) : (20\bar{1})$...	41	52 25– 53 9	52 49	52 48	1	52 49
$r'p = (\bar{2}01) : (110)$...	41	126 50–127 30	127 11	127 12	1	127 11
Total (11 crystals)...	634					

Fig. 9.



Optic Axial Angle.—The results for 2E and for $2H_a$, $2H_o$, and the true angle $2V_a$, from three pairs of plates, ground perpendicular to the two bisectrices, are given in the next two tables.

Apparent Optic Axial Angle in Air, 2E, of AmMn Selenate.

Light.	Plate I.	Plate II.	Plate III.	Mean 2E.
Li....................	118° 33′	119° 36′	123° 57′	120° 42′
C	118 39	119 41	124 2	120 47
Na	119 54	121 4	124 32	121 50
Tl....................	120 45	122 28	125 41	122 58
Cd	121 25	123 10	126 25	123 40

Determination of True Optic Axial Angle in Bromonaphthalene.

Light.	No. of plate perp. 1 M.L.	Observed $2H_a$.	No. of plate perp. 2 M.L.	Observed $2H_o$.	Calculated $2V_a$.	Mean $2V_a$.
Li.........	1	63° 36′	1*a*	97° 10′	70° 11′	70° 17′
	2	63 35	2*a*	97 11	70 10	
	3	63 54	3*a*	96 52	70 32	
C	1	63 35	1*a*	97 6	70 12	70 18
	2	63 34	2*a*	97 9	70 10	
	3	63 53	3*a*	96 49	70 33	
Na	1	63 27	1*a*	96 30	70 21	70 23
	2	63 27	2*a*	96 51	70 12	
	3	63 42	3*a*	96 26	70 35	
Tl.........	1	63 18	1*a*	96 0	70 28	70 28
	2	63 8	2*a*	96 11	70 15	
	3	63 31	3*a*	95 51	70 40	
Cd	1	63 10	1*a*	95 34	70 32	70 31
	2	62 56	2*a*	95 40	70 18	
	3	63 24	3*a*	95 37	70 42	
F	1	63 0	1*a*	95 0	70 39	70 34
	2	62 40	2*a*	95 10	70 20	
	3	63 14	3*a*	95 16	70 43	

Dispersion of the Median Lines.—This was determined by immersion in monochlorobenzene, the refractive index for which is close to the mean index for the crystals. It was found to be so small, less than 5 minutes, that it was not possible to be certain of its sign, different plates showing the first median line to be nearer to axis a for red and blue respectively.

Effect of Temperature on Optic Axial Angle.—The angle in air 2E decreased 6° 40′ to 115° 10′ for sodium light, on raising the temperature of the section-plate gradually from the ordinary temperature (15°) to 75° C.

Refractive Indices.—Results with six 60°-prisms, each ground to afford two indices directly—

Refractive Indices of Ammonium Manganese Selenate.

Light.	α.	β.	γ.
Li	1·5124	1·5163	1·5249
C	1·5129	1·5169	1·5255
Na	1·5160	1·5202	1·5288
Tl	1·5194	1·5237	1·5323
Cd	1·5214	1·5256	1·5343
F	1·5235	1·5276	1·5364
G	1·5294	1·5340	1·5429

Mean of α, β, and γ for Na light = 1·5217.

α = Vibration direction parallel to second median line, 3° 22′ in front of vertical axis c.
β = „ „ „ symmetry axis b.
γ = „ „ „ first median line, 12° 54′ above inclined axis a.
Double refraction, $\mathrm{Na}_{\gamma-\alpha}$ = 0·0128.

General formula for β, corrected to a vacuum :—

$$\beta = 1{\cdot}5023 + \frac{690\ 197}{\lambda^2} - \frac{1\ 906\ 400\ 000\ 000}{\lambda^4} + \ldots .$$

The α indices are equally well reproduced by the formula if the constant 1·5023 be diminished by 0·0042, and the γ indices if it be increased by 0·0086.

Observations at 65° indicated that the refractive indices of ammonium manganese selenate diminish by about 0·0010 for a rise of temperature of 50°.

Axial Ratios of the Optical Ellipsoid.—

$$\alpha : \beta : \gamma = 0{\cdot}9972 : 1 : 1{\cdot}0057, \qquad \mathfrak{a} : \mathfrak{b} : \mathfrak{c} = 1{\cdot}0028 : 1 : 0{\cdot}9944.$$

Molecular Optical Constants.

	Axis of optical indicatrix.		α.	β.	γ.
Lorenz	Specific refraction, $\frac{n^2-1}{(n^2+2)\,d} = \mathfrak{n}$	C	0·1393	0·1402	0·1422
		G	0·1430	0·1440	0·1460
	Molecular refraction, $\frac{n^2-1}{n^2+2} \cdot \frac{M}{d} = \mathfrak{m}$	C	67·12	67·56	68·51
		G	68·93	69·43	70·39
	Specific dispersion, $\mathfrak{n}_G - \mathfrak{n}_C$		0·0037	0·0038	0·0038
	Molecular dispersion, $\mathfrak{m}_G - \mathfrak{m}_C$		1·81	1·87	1·88
Gladstone	Molecular refraction, $\frac{n-1}{d}\,M$	C	114·55	115·45	117·37

Mean molecular refraction (Gladstone), $\frac{1}{3}(\alpha+\beta+\gamma)$ = 115·79.

Comparison of Results.

Habit.—The crystals of the rubidium and cæsium salts exhibit the habits which are respectively characteristic of rubidium and cæsium salts throughout the whole series of double sulphates and selenates.

Crystal Elements and Angles.—

Comparison of the Interfacial Angles.

Angle.	RbMn selenate.	CsMn selenate.	AmMn selenate.
	° ′	° ′	° ′
$ac = (100) : (001)$	74 51	73 38	73 44
$as = (100) : (101)$	45 52	44 59	45 14
$sc = (101) : (001)$	28 59	28 39	28 30
$cr' = (001) : (\bar{2}01)$	63 35	64 35	64 12
$cs' = (001) : (\bar{1}01)$	38 20	38 48	38 28
$s'r' = (\bar{1}01) : (\bar{2}01)$	25 15	25 47	25 44
$r'a = (\bar{2}01) : (\bar{1}00)$	41 34	41 47	42 4
$ap = (100) : (110)$	35 38	35 4	35 29
$ap'' = (100) : (210)$	19 43	19 20	19 37
$p''p = (210) : (110)$	15 55	15 44	15 52
$pp' = (110) : (120)$	19 28	19 28	19 28
$p'b = (120) : (010)$	34 54	35 28	35 3
$pp''' = (110) : (130)$	29 25	29 31	29 27
$p'''b = (130) : (010)$	24 57	25 25	25 4
$p'p''' = (120) : (130)$	9 57	10 3	9 59
$pb = (110) : (010)$	54 22	54 56	54 31
$cq = (001) : (011)$	25 48	25 26	25 37
$qb = (011) : (010)$	64 12	64 34	64 23
$ao = (100) : (111)$	49 4	48 7	48 25
$oq = (111) : (011)$	27 19	27 8	26 57
$aq = (100) : (011)$	76 23	75 15	75 22
$qo' = (011) : (\bar{1}11)$	34 33	35 3	34 43
$o'a = (\bar{1}11) : (\bar{1}00)$	69 4	69 42	69 55
$co = (001) : (111)$	34 35	34 5	34 5
$op = (111) : (110)$	43 9	42 35	42 44
$cp = (001) : (110)$	77 44	76 40	76 49
$po' = (110) : (11\bar{1})$	57 44	58 27	58 27
$o'c = (11\bar{1}) : (00\bar{1})$	44 32	44 53	44 44
$bn = (010) : (121)$	54 18	54 58	54 39
$no = (121) : (111)$	15 56	15 43	15 50
$bo = (010) : (111)$	70 14	70 41	70 29
$os = (111) : (101)$	19 46	19 19	19 31
$bo' = (010) : (\bar{1}11)$	65 17	65 23	65 11
$o's' = (\bar{1}11) : (\bar{1}01)$	24 43	24 37	24 49
$sq = (101) : (011)$	38 2	37 35	37 35
$qp = (011) : (\bar{1}10)$	86 26	87 48	87 24
$ps = (\bar{1}10) : (\bar{1}0\bar{1})$	55 32	54 37	55 1
$s'q = (\bar{1}01) : (011)$	45 4	45 16	45 5
$qn = (011) : (121)$	26 41	26 26	26 18
$np = (121) : (110)$	36 55	36 30	36 32
$qp = (011) : (110)$	63 36	62 56	62 50
$ps' = (110) : (10\bar{1})$	71 20	71 48	72 5
$r'o' = (\bar{2}01) : (\bar{1}11)$	34 45	35 3	35 9
$o'p = (\bar{1}11) : (110)$	92 42	92 34	92 3
$pr' = (110) : (20\bar{1})$	52 33	52 23	52 48

The interfacial angles of the rubidium and cæsium salts bear the same relations to each other as do the angles of the rubidium and cæsium salts of all the other groups of the series investigated, the signs of the differences being the same. The axial ratios are also similarly related. The angles and ratios of the ammonium salt are adequately close for true isomorphism, but are not eutropically related to the metallic salt-values. The values of the great majority of the angles are intermediate between the values for the two metallic salts.

Comparison of the Axial Angles and Axial Ratios.

	Axial angles.	Axial ratios.
	β.	$a : b : c$
Rubidium manganese selenate	105° 9′	0·7422 : 1 : 0·5008
Ammonium „ „	106° 16′	0·7427 : 1 : 0·4994
Cæsium „ „	106° 22′	0·7319 : 1 : 0·4957

Volume Constants.—

Volume Constants of the Manganese Group of Double Selenates.

Salt.	Molecular weight	Specific gravity.	Molecular volume.	Topic axial ratios.
				$\chi : \psi : \omega$
RbMn selenate	615·92	2·763	222·92	6·3333 : 8·5332 : 4·2734
CsMn „	709·92	3·008	236·01	6·4297 : 8·7850 : 4·3547
NH_4Mn „	481·98	2·158	223·35	6·3577 : 8·5603 : 4·2750

The usual progression observed in the series, with the atomic number of the alkali metal, is apparent in molecular volume and topic axial ratios on passing from the rubidium to the cæsium salt; and the ammonium salt is, as usual, practically isostructural with the rubidium salt, the molecular volumes and topic axial ratios (relative dimensions of the elementary cells of the space-lattices) being nearly identical.

There is an increase of molecular volume of 13·09 units on replacing rubidium by cæsium, an amount of the same order as was observed in the iron group (12·92) of double selenates, and in the manganese (12·69) and iron (12·96) groups of double sulphates.

Cleavage.—There is a perfect cleavage parallel to the orthopinakoid $r'\{\bar{2}01\}$ in the crystals of all three salts. This is the common cleavage direction of the whole series of double sulphates and selenates. In addition, however, ammonium manganous selenate cleaves with facility along the symmetry plane $b\{010\}$.

Orientation of Optical Ellipsoid.—The position of the ellipsoid is conveniently determined by giving the position, for a specific wave-length, of that one of its two rectangular axes lying in the symmetry plane which is not far removed from the vertical crystal axis *c*; it is the α axis of the indicatrix and the second median line for all the salts.

Inclination of α Axis of Indicatrix to Vertical Axis *c*, in front, for Na Light.

NH_4Mn selenate	3° 22′
RbMn ,,	13° 7′
CsMn ,,	22° 11′

It will be observed that the position of this axis for the ammonium salt is nearest the vertical axis *c*, and that the optical ellipsoid rotates further and further away from this position, in the symmetry plane, for the rubidium and cæsium salts, as in all the other groups of the series previously studied. Fig. 10 gives a comparative view of the positions of the axes of the indicatrix lying in the symmetry plane for all three salts, and will render the meaning of this table of inclinations clear.

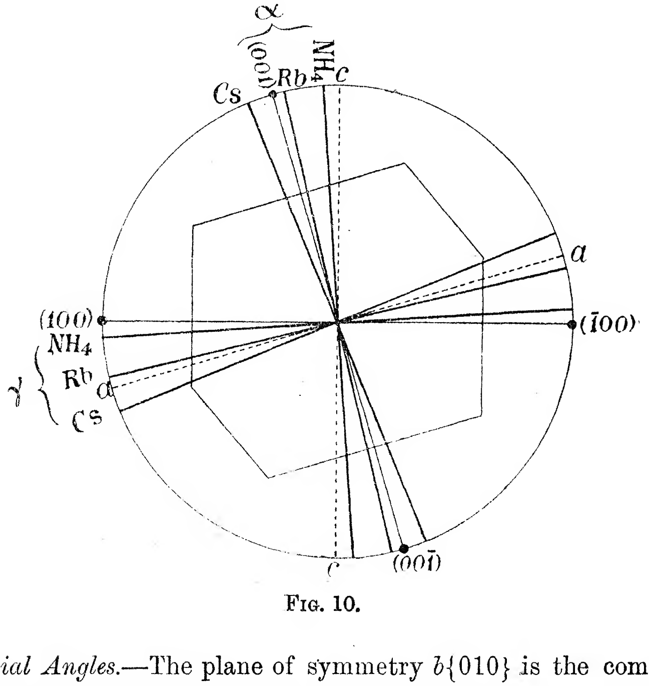


Fig. 10.

Optic Axial Angles.—The plane of symmetry *b*{010} is the common plane of the optic axes for the whole group. The optic axial angles are as follows.

In the absence of a potassium salt a complete comparison is not possible, but the relations are similar to those in other groups.

Optic Axial Angles $2V_a$ of the Manganese Group of Double Selenates.

	AmMn selenate.	RbMn selenate.	CsMn selenate.
Li	70° 17′	66° 5′	69° 3′
C	70 18	66 5	69 1
Na	70 23	66 2	68 49
Tl	70 28	66 0	68 33
Cd	70 31	65 57	68 17
F	70 34	65 52	68 5

Refractive Indices.—The refractive indices are compared in the accompanying Table. Both the refractive index and the double refraction change progressively, the former increasing and the latter decreasing with the atomic number of the alkali metal, and the indices of the ammonium salt are intermediate between those for the two alkali metallic salts.

Comparison of the Refractive Indices.

Index.	Light.	RbMn selenate.	NH_4Mn selenate.	CsMn selenate.
α	Li	1·5059	1·5124	1·5215
	C	1·5064	1·5129	1·5220
	Na	1·5094	1·5160	1·5250
	Tl	1·5125	1·5194	1·5283
	Cd	1·5143	1·5214	1·5302
	F	1·5163	1·5235	1·5323
	G	1·5225	1·5294	1·5379
β	Li	1·5105	1·5163	1·5243
	C	1·5110	1·5169	1·5248
	Na	1·5140	1·5202	1·5279
	Tl	1·5172	1·5237	1·5312
	Cd	1·5190	1·5256	1·5331
	F	1·5210	1·5276	1·5350
	G	1·5270	1·5340	1·5405
γ	Li	1·5220	1·5249	1·5301
	C	1·5226	1·5255	1·5306
	Na	1·5258	1·5288	1·5338
	Tl	1·5292	1·5323	1·5373
	Cd	1·5312	1·5343	1·5394
	F	1·5332	1·5364	1·5415
	G	1·5396	1·5429	1·5471
Mean refractive index $\frac{1}{3}(\alpha + \beta + \gamma)$ for Na light		1·5164	1·5217	1·5289
Double refraction, $Na_{\gamma-\alpha}$		0·0164	0·0128	0·0088

Axial Ratios of the Optical Indicatrix.—These are as under, and are related for the three salts just as in other groups of the series.

Axial Ratios of the Optical Indicatrix.

	$\alpha : \beta : \gamma$
RbMn selenate	0·9969 : 1 : 1·0078
NH_4Mn „	0·9972 : 1 : 1·0057
CsMn „	0·9981 : 1 : 1·0039

Molecular Optical Constants.—The molecular refraction increases with the atomic number of the alkali metal, and the value for the ammonium salt is about the same as that for the rubidium salt, corresponding to the isostructure of the two salts.

Specific Refraction and Dispersion (Lorenz).

Selenate.	Specific refraction, $\frac{n^2-1}{(n^2+2)\,d}=\mathrm{n}$.						Specific dispersion. $\mathrm{n}_G-\mathrm{n}_C$.		
	For ray C(Hα).			For ray Hγ near G.					
	α.	β.	γ.	α.	β.	γ.	α.	β.	γ.
AmMn ...	0·1393	0·1402	0·1422	0·1430	0·1440	0·1460	0·0037	0·0038	0·0038
RbMn ...	0·1076	0·1084	0·1105	0·1105	0·1113	0·1135	0·0029	0·0029	0·0030
CsMn......	0·1014	0·1018	0·1028	0·1040	0·1044	0·1054	0·0026	0·0026	0·0026

Molecular Refraction and Dispersion (Lorenz).

Selenate.	Molecular refraction, $\frac{n^2-1}{n^2+2}\cdot\frac{M}{d}=\mathrm{m}$.						Molecular dispersion. $\mathrm{m}_G-\mathrm{m}_C$.		
	For ray C (Hα).			For ray Hγ near G.					
	α.	β.	γ.	α.	β.	γ.	α.	β.	γ.
RbMn	66·27	66·78	68·06	68·04	68·53	69·90	1·77	1·75	1·84
AmMn..................	67·12	67·56	68·51	68·93	69·43	70·39	1·81	1·87	1·88
CsMn	71·98	72·30	72·97	73·81	74·10	74·86	1·83	1·80	1·89

Molecular Refraction (Gladstone and Dale).

Selenate.	$\frac{n-1}{d}$ M for ray C.			Mean molecular refraction for ray C. $\frac{1}{3}(\alpha+\beta+\gamma)$.
	α.	β.	γ.	
RbMn	112·88	113·91	116·50	114·43
AmMn............................	114·55	115·45	117·37	115·79
CsMn	123·20	123·86	125·23	124·10

General Conclusions.

It has thus been found that the crystals of the hexahydrated rubidium manganous and cæsium manganous selenates exhibit the same progression in all their properties—morphological (habits, interfacial angles, axial angles, and space-lattice cell-dimensions) and optical—with the progressive increase of the atomic number of the alkali metal, which has been observed throughout every group (salts containing the same M-metal) of this great series of isomorphous salts, $\mathrm{R_2M(\overset{S}{Se}O_4)_2.6H_2O}$.

If the potassium salt of the group could be obtained there is no doubt it would fall into line as the first member of the group, and it is even possible to specify what its constants would be, within a very slight margin of possible error. Moreover, ammonium manganous selenate hexahydrate is almost exactly isostructural with its rubidium analogue, a fact in line with the results afforded for all analogous pairs of ammonium and rubidium salts throughout both this monoclinic series and the rhombic series of simple salts, $R_2{}^{S}_{Se}O_4$.

Monoclinic Double Selenates of the Cadmium Group.

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Like the manganese group, the cadmium group of hexahydrated double selenates consists of only three salts, those containing rubidium, cæsium, and ammonium, the potassium salt being incapable of preparation and apparently of existence. A potassium cadmium selenate with two molecules of water is obtained instead, and was described by Von Hauer in the year 1866, and by Topsøe in 1870.* Indeed, so near in this group is even the rubidium salt to the limit of existence that it has only been obtained at all after many and prolonged attempts. Moreover, it was only formed then in small quantity in the very coldest weather, the great majority of crystals even in these few crops having been those of the salt just referred to with other than six molecules of water. Almost as great difficulty has also been found in preparing the cæsium salt, and the crystals of both these alkali metallic salts of the hexahydrated group have always been white and opaque, so that no optical investigation has been possible. These salts, indeed, would appear never to have been previously obtained at all. Moreover, the ammonium salt, which was obtained by Von Hauer and measured by Topsøe,* affords crystals which are for the most part opaque, and are described by Topsøe as being porcelain-like. No optical investigation of them has ever previously been attempted; they were not included by Topsøe and Christiansen in their great work. The author has succeeded, however, in obtaining a very few crystals of ammonium cadmium selenate hexahydrate, which remained sufficiently transparent for the few hours, after their removal from the mother liquor, necessary to enable them to be subjected to a fairly complete optical investigation. The method followed was the rapid one used in the even more difficult case of potassium ferrous selenate.†

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* Haldor Topsøe, 'Krystallogr.-kem. Unders. o. de Selensure Salte,' Copenhagen, 1870.

† 'Phil. Trans.,' A, vol. 218, p. 401 (1919).